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The dark side of the sun: How solar power production affects the market value of solar and gas sources ☆

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ABSTRACT

Using daily data for the Italian wholesale day-ahead power market over the period 2008–2013, we assess the impact of solar production on the market value of solar and gas sources, defined using the concepts of value factor and unit revenues. We find that, on average, solar generation negatively affects the solar source market value, causing a departure from the grid parity condition and mining their competitiveness once public incentives are removed. This negative relation is not constant over time and becomes stronger for increasing solar penetration in the energy mix. Interestingly, the opposite is found when looking at gas. While the relation between solar production and the gas market value is negative or not significant when the former is low, it turns positive for higher levels of solar production. This is the result of a change in gas producers' bidding strategies. Indeed, in the Italian power market the highest hourly price has shifted from the peak daytime, when solar production is concentrated, to the off-peak nighttime, when solar is absent from the market and gas can exploit temporary market power.

1. Introduction

The increase in the employment of renewable energy sources (RES) constitutes one of the pillars of the European Climate and Energy Strategy. By 2020, at least 20% of the final energy consumption will have to be covered by RES at a European level (Directive, 2009/28/EC), and this share will have to increase at least to 27% by 2030 (COM(2014) 15 final). In recent years, several EU Member States have implemented different types of RES supporting schemes to reach the 2020 RES target. By granting an economic return above the market price, these schemes have favored an increase of RES in the energy mix that allegedly would have not occurred.

This topic has gained increasing attention in the literature. A widely agreed result is that the deployment of RES brings about a decline in the daily average wholesale electricity price, a phenomenon also known as the *merit-order effect*. Having low operational costs, RES enter at the base of the merit-order function and crowd plants with relatively high marginal costs out of the market. However, since RES (in particular solar) production is not uniform during the day, its impact on the electricity price will likely be uneven in the 24 h. Therefore, not only should we observe a switch of power generation from traditional sources to renewable ones; there will also be a change in the price earned by each source at the time of producing. This, in turn, affects the economic returns of different technologies in a non-homogenous way.

This topic constitutes the core of our analysis, which is applied to the Italian power market, where solar public incentives have been among the highest in the world (IEA 2011; EPIA, 2012; IEA, 2013).

We focus on solar and gas sources, as the former has experienced a significant growth in production, while the latter covers the highest share of the national energy mix in Italy.

The goal of this paper is to assess the different impact of solar production on the market value of solar and gas sources, measured by: 1) their unit revenues, defined as the daily average of the production-weighted price earned by selling electricity in each hour of the day; and 2) their value factor, an index calculated as the ratio

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between the unit revenues and the average daily price. The value of this index depends on the hourly distribution of price and power generation. Indeed, it equals 1 only when either power generation or the electricity price is distributed uniformly along the 24 h of the day, as only in this case the unit revenues earned by a given technology would equal the daily average price. Conversely, the value factor is greater (lower) than 1 when production from a given technology is concentrated in those hours where the market clears at a price higher (lower) than the daily average value.

After analyzing the trend of the value factor and unit revenues for both solar and gas sources over the period 2008–2013, we develop a quantitative analysis to assess whether, and to which extent, a variation of the solar share has affected the VFs of solar and gas sources. Then, we disentangle the differential impact of solar power generation and energy consumption on the VFs and unit revenues for both solar and gas sources. The analysis is first developed over the entire period 2008–2013 and then over three sub-periods where different solar supporting schemes were in place.

We expect that, by favoring a decline of the electricity price, the deployment of solar generation is associated with a fall in its unitary economic returns. From this point of view, while public supporting schemes make solar energy more attractive in the short run, an excessive penetration of this technology in the energy mix may be associated with a departure from the grid parity condition.

We also expect that solar penetration impacts on the market value of solar and gas sources unevenly. Indeed, solar production mainly depends on exogenous weather conditions and cannot be modulated strategically according to market price signals. Conversely, gas is a dispatchable technology and can adapt its bidding strategies to exogenous market conditions.

The value added of this paper is that, to the best of our knowledge, no previous study has quantified the impact of RES penetration on the market value of traditional sources with respect to that of renewable sources themselves; moreover, no paper has applied this type of analysis to the Italian case, which has experienced a significant increase in solar power generation.

The paper is structured as follows. Section 2 offers a brief review of the related literature; Section 3 presents the dataset and the empirical approach adopted in this paper. Section 4 reports the results of the econometric analysis and Section 5 offers and interpretation of the results. Section 6 concludes.

2. Related literature

The impact of RES development on the electricity price has gained increasing attention in the literature. While some papers have analyzed the merit-order effect on a theoretical basis (Fischer, 2006; Jensen and Skytte, 2002), others have found supporting empirical evidence in several electricity markets (Sensfuss et al., 2008; Milstein and Tishler, 2011). Some of these papers have focused on the impact of the price reduction induced by RES penetration on consumers' welfare. The results are not univocal. Gelabert et al. (2011) and Würzburg et al. (2013) respectively find that the decline of the wholesale power price favored by RES penetration in the Spanish and German markets offsets the cost of the subsidy passed through to the final price, bringing about an improvement in consumers surplus. Conversely, Moreno et al. (2012) find that, in several EU countries, electricity prices paid by consumers increase with RES deployment. Recently, Clò et al. (2015) focus on the Italian power market and find that the monetary savings promoted by solar production are not sufficient to compensate the cost of the related supporting schemes, while the opposite occurs in the case of wind.

Other papers point out that RES deployment not only reduces the electricity price, but also increases its volatility (Jonsson et al., 2010; Woo et al., 2011). This, in turn, risks to reduce the economic returns from selling electricity and to lower the long-run propensity to invest in new power capacity (Ketterer, 2014).

A second strand of literature analyzes the impact of RES supporting schemes on RES deployment towards grid parity. Some papers argue that, by stimulating innovation and diffusion of renewable technologies, supporting schemes promote the RES industry and favor a reduction of the RES levelized cost of energy, making RES closer to the break-even point (De La Tour et al., 2013; Johnstone et al., 2010; Lund, 2011). While the mentioned papers focus on the cost side, others analyze how supporting schemes and the related development of RES are likely to impact on their revenues. Borenstein (2008) highlights that the RES market value strongly depends on the time at which electricity is produced. Since solar power generation is highly concentrated in the hours when price is higher than average due to peak demand, such timing is likely to increase the solar market value.

Several works analyze this topic focusing on the value factor (among others Sensfuss et al., 2008; Green and Vasilakos, 2012; Brown and Rowlands, 2009). As stressed by Stephenson (1973), the value factor measures the value of electricity non-uniformly produced along the day with respect to a flat profile and, thus, indicates whether a given technology has a market value higher or lower than average. Therefore, this index compares the prices that intermittent RES sources actually receive with the hypothetical value in the case their production was invariant (Fripp and Wiser, 2008). Hirth (2013) finds that an increase of wind and solar share is associated with a reduction of their relative VFs. This suggests that RES penetration reduces the RES relative price more than the daily average price.

Along this line, Sioshansi (2011) and Haas et al. (2013) analyze respectively the impact of wind and solar power in the energy markets and their analysis is helpful to understand why the value factor for renewable sources is likely to decrease with RES penetration. According to Sioshansi (2011), wind power has a lower market value than other technologies that can store production and bid strategically. Similarly, Haas et al. (2013) show that an increase of solar capacity directly reduces the electricity price when solar power is available, while it indirectly increases the price at which electricity is offered by conventional power plants in the hours when RES are scarce. This suggests that RES penetration may reduce the RES market value more than the traditional sources' one.

3. Data and methods

We use hourly data for the Italian day-ahead wholesale electricity market on prices, demand and power generation differentiated by energy source. Data provided by the Italian *Gestore dei Mercati Energetici* (GME) are available since 2005; however, solar production and its market share were negligible until 2007 (the latter was still below 0.4% in 2007); thus, we narrow our empirical analysis to the period from January 1st, 2008 until October 31st, 2013.

First of all, we calculate the daily sum of hourly revenues as:

$$R_d^s = \sum_{t=1}^{24} p_t q_t^s \tag{1}$$

where R_d^s are the daily revenues of each technology source; s = gas, solar; p_t is the hourly price and q_t^s is the hourly output of each energy source. Then, to catch the non-uniform distribution of price and power generation by source along the day, we calculate the daily unit revenues, p_d^s, as the ratio of R_d^s to the daily output of each energy source s. Unit revenues are therefore defined as the weighted average price received by each technology each day:

$$p_d^s = \frac{R_d^s}{\sum_{t=1}^{24} q_t^s}. \tag{2}$$